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Indian Standard (Reaffirmed 2004)

SPECIFICATION FOR CERAMIC INSULATING MATERIALS FOR ELECTRICAL PURPOSES

First Reprint JULY 1983

(Incorporating Amendment No. 1)

UDC 621·315·612

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Gr 6 ***September* 1978**

Indian Standard
SPECIFICATION FOR CERAMIC INSULATING MATERIALS FOR ELECTRICAL PURPOSES.

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Indian Standard
SPECIFICATION FOR CERAMIC INSULATING MATERIALS FOR ELECTRICAL PURPOSES

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 21 February 1978, after the draft finalized by the Electrical Insulators and Accessories Sectional Committee had been approved by the Electrotechnical Division Council.

0.2 This standard is intended mainly for designers of electrical equipment like insulators and bushings except for equipment required for telecommunication and allied purposes for which a separate Indian Standard (IS : 6659-1971*) is available. It provides, as far as possible, methods of test to permit comparison of technical data of ceramic materials used for the manufacture of insulators and bushings. Specialized capacitor materials are not covered. This standard does not provide all the tests appropriate to materials intended for refractories and gas-tight envelopes.

0.3 It is important to recognize that the values for physical properties given as qualifying limits in the standard are specific for the test specimens employed when tested by the methods described. It should not be assumed that any test condition represents a safe working condition.

0.4 This standard is based on the properties of good quality materials which are commercially available. It is not always possible to manufacture every material specified in this standard in all shapes and sizes, and the characteristics of a particular component made of a ceramic material depends on whether it is made by pressing a granulated material (pressed material) or by shaping a plastic material (plastic material). Such limitations should be discussed with the manufacturers of ceramic materials at the time of enquiry.

0.5 It has been considered unnecessary to specify methods of test for some inherent characteristics of ceramic materials, but the following may be of interest to some users of these materials.

0.5.1 Ceramic materials are resistant to deterioration from electric arc unless the heat generated is so intense that it causes fusion of the material or thermal spalling. Tests devised for organic materials, such as plastomers and elastomers, do not apply to ceramic materials. Ceramic materials are non-tracking, as a result of their inorganic composition and refractory nature.

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*Specification for ceramic insulating materials for telecommunication and allied purposes.

0.5.2 All ceramic materials within the scope of this standard are resistant to hydrolysis and they are generally resistant to attack by chemicals (with the exception of hydrofluoric acid). It is commonly arranged between the manufacturer and the purchaser that ceramic materials, required to be physically and chemically stable, shall not show obvious signs of deterioration when maintained under agreed conditions, designed to simulate service conditions.

0.5.3 The materials covered by this standard are highly resistant to abrasion and have a hardness of 7 to 9, measured on Moh's scale.

0.5.4 These materials are normally of excellent dimensional stability, but a few rare cases are known where there has been a definite dimensional change or obvious sign of deterioration over a considerable period of time. It is not at present practicable to specify a test for checking this.

0.6 In the preparation of this standard, assistance has been derived from BS 1598 : 1964 ' Specification for ceramic insulating materials for general electrical purposes', issued by the British Standards Institution.

0.7 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard covers ceramic materials, either moulded, cast or extruded, to be used in the manufacture of bushings and insulators. It provides a classification of these materials based on their electrical characteristics.

It specifies limits and methods of test for electrical, mechanical, thermal and other general properties of the materials.

2. TERMINOLOGY

2.0 For the purpose of this standard, the following definitions shall apply.

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*Rules for rounding off numerical values (*revised*).

2.1 Ceramic Materials — Inorganic materials which are consolidated into the final vitreous state (*see* **2.6**) by application of heat while substantially retaining their unfired shape.

2.2 Pressed Process — A process of shaping ceramic materials by means of pressing the material, in granulated or powder form, in a die.

2.3 Plastic Process — A process of shaping ceramic materials by means of extrusion, jelleying or casting followed, when necessary, by turning.

2.4 Dielectric Dissipation Factor — It is the tangent of the loss angle (tan δ).

2.5 Temperature Coefficient of Capacitance — The temperature coefficient of capacitance, over a range of T_1°C to T_2°C is equal to $\frac{(C_2 - C_1)\ 10^6}{C_1\ (T_2 - T_1)}$ parts per million per °C

where

C_1 = the capacitance of sample at T_1°C, and
C_2 = is the capacitance of sample at T_2°C.

NOTE — The temperature coefficient of capacitance of the material is identical with that of a capacitor, having the material as dielectric, and constructed in such a manner that change of capacitance with temperature is solely determined by the properties of the dielectric and not by the electrodes. This implies that the electrodes should consist of thin continuous metal films firmly attached to the surface of material so that thermal expansion of the electrodes is controlled by the dielectric.

2.6 Vitreous — Ceramic materials are termed vitreous if they show an increase in weight of less than 0·5 percent when subjected to water absorption test as described in Appendix M.

NOTE 1 — Materials with zero apparent porosity are impermeable.

NOTE 2 — The term 'vitreous' is not strictly accurate, but it is convenient for the purpose of this specification.

2.7 Standard Deviation — The square root of the quotient obtained by dividing the sum of square of deviation of the observation from their mean by the number of observations.

If $x_1, x_2 \ldots\ldots\ldots\ldots x_n$ are the n observations with mean $\bar{x}$, then standard deviation is calculated as:

$$s = \sqrt{\frac{(x - \bar{x})^2}{n}}$$

2.8 Coefficient of Variation — The ratio of the standard deviation to the absolute value of the arithmetic mean.

NOTE — This ratio may be expressed as a percentage.

2.9 Mean (Arithmetic Mean) — Sum of the values of the observations divided by the number of observations.

If x_1, x_2...............x_n are n values, then the arithmetic mean is calculated as:

$$\bar{x} = \frac{x_1 + x_2 \dots\dots\dots\dots\dots + x_n}{n}$$

2.10 Geometric Mean — The positive nth root of the product of n observations.

If x_1, x_2 ....x_n are n values, the geometric mean is calculated as:

$$GM = (x_1 \times x_2 \times x_3 \dots\dots\dots\dots\dots x_n)^{\frac{1}{n}} = \sqrt[n]{x_1 \times x_2 \dots x_n}$$

3. CLASSIFICATION

3.1 The materials covered by this standard are classified according to the characteristics specified in Table 1.

4. TEST REQUIREMENTS

4.1 The material shall meet the requirements of the following tests:

a) Dielectric dissipation factor and permittivity (*see* **5.1**),
b) Power frequency electric withstand strength (*see* **5.3**),
c) Surface resistivity (*see* **5.4**),
d) Volume resistivity (*see* **5.5**),
e) Cross-breaking strength (*see* **6.1**),
f) Coefficient of linear expansion (*see* **7.1**), and
g) Porosity (*see* **8.1**).

4.2 The test values of ceramic materials are dependant to some extent on the preparation of test specimens used. The test specimens used shall therefore be prepared by process similar to that to be used in production (that is, by pressing or plastic methods as applicable). The specimens, however, shall not be glazed.

4.3 The preparation and conditioning of test pieces shall be done in accordance with Appendix A.

TABLE 1 CLASSIFICATION AND QUALIFYING LIMITS OF CERAMIC INSULATING MATERIALS

(*Clause* 3.1)

CLASS OF MATERIAL	METHOD OF MAKING	MAXIMUM DIELECTRIC DISSIPATION FACTOR AT 1 MHz (*see* APPENDIX B)	MAXIMUM PERMITTIVITY AT 1 MHz (*see* APPENDIX B)	POWER FREQUENCY WITHSTAND STRENGTH (*see* APPENDIX D)	MINIMUM SURFACE RESISTIVITY (*see* APPENDIX E)	MINIMUM VOLUME RESISTIVITY (*see* APPENDIX F)			MINIMUM CROSS BREAKING STRENGTH (*see* APPENDIX G)	MINIMUM COMPRESSIVE STRENGTH (*see* APPENDIX H)	COEFFICIENT OF LINEAR EXPANSION (*see* APPENDIX J)		POROSITY	
						20°C	300°C	600°C			20 to 100°C	20 to 500°C	Penetration (*see* Appendix L)	Percent Increase in Mass (*see* Appendix M)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
		$\times 10^{-4}$		kV (rms)	M Ω		M Ω cm		N/mm²	N/mm²	$\times 10^{-6}$ per deg C			
1	a) Pressed b) Plastic	2·7 2·7	7·5	20 25	10^8	10^7	10^5	10^2	60 100	300	7·5 to 8·5	7·2 to 8·2	Nil	Nil
2	a) Pressed b) Plastic	5·3 5·3	7·5	20 25	10^8	10^7	10^4	10	60 100	300	7·5 to 8·5	7·2 to 8·2	Nil	Nil
3	a) Pressed b) Plastic	10·7 10·7	7·5	20 25	10^8	10^7	10^3	1	60 100	300	7·5 to 8·5	7·2 to 8·2	Nil	Nil
4	a) Pressed b) Plastic	10·0 10·0	12	5 25	10^8	10^7	10^3	0·1	30 70	300	3·0 to 6·5	3·0 to 7·0	Nil	Nil
5	a) Pressed b) Plastic	21·3 21·3	7·5	20 25	10^8	10^7	10^3	0·1	60 100	300	7·5 to 8·5	7·2 to 8·5	Nil	Nil
6	a) Pressed b) Plastic	80·0 80·0	7·5	5 25	10^8	10^7	10	0·01	30 70	300	3·0 to 6·5	3·0 to 7·0	— Nil	0·5 —
7	a) Pressed b) Plastic	80·0 80·0	7·5	5 25	10^8	10^5	10	0·01	30 70	300	2·0 *Max*	3·0 *Max*	Nil	—
8	a) Pressed b) Plastic	10·0 10·0	12	25	10^8	10^7	10^4	10	200	500	6·0 to 7·5	6·5 to 8·0	Nil	Nil
9	a) Pressed b) Plastic	28·3 28·3	12	25	10^9	10^7	10^3	1	150	500	6·0 to 7·5	6·5 to 8·0	Nil	Nil

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5. ELECTRICAL PROPERTIES

5.1 Dielectric Dissipation Factor and Permittivity — The material shall be tested at a frequency of 1 MHz by the method described in Appendix B.

The results shall be stated as the mean value of (a) permittivity, and (b) dielectric dissipation factor, and shall meet the requirements given in Table 1.

NOTE — The test may also be used for other frequencies, between 50 Hz and 10 kHz by the methods described for audio frequencies, or between 10 kHz and 30 MHz by the methods described for radio frequencies. In such cases suitable limits should be agreed between the supplier and the purchaser.

5.2 Temperature Coefficient of Capacitance of a Material Over a Given Temperature Range

5.2.1 When required by the purchaser, the material shall be tested by the method described in Appendix C. The results shall be stated as the temperature coefficients of capacitance of the three specimens over the range 20 – 85°C. Other temperature ranges may be specified by agreement between the purchaser and the supplier. With repeated temperature cycles the above measurements may disclose non-cyclic variations of capacitance with temperature. If necessary, agreement on this point should be reached between the manufacturer and the purchaser.

5.2.2 Where the temperature coefficient of permittivity is required, this may be obtained from the following relationship:

$$\left.\begin{array}{l}\text{Temperature coefficient}\\ \text{of permittivity}\end{array}\right\} = \begin{array}{l}\text{Temperature coefficient of capacitance}\\ \text{— coefficient of thermal expansion}\end{array}$$

5.3 Power Frequency Electric Withstand Strength — The material shall be tested by the method described in Appendix D, and shall withstand the voltage given in Table 1.

5.4 Surface Resistivity — The material shall be tested by the methods described in Appendix E. The results shall be stated as mean surface resistivity in megohms, and shall meet the requirements given in Table 1.

5.5 Volume Resistivity — The material shall be tested by the methods described in Appendix F, and unless otherwise agreed the test shall be made only at 27°C. The results shall be stated as mean volume resistivity, in magohm-centimetres, together with the temperature of test, and shall meet the requirements given in Table 1.

6. MECHANICAL PROPERTIES

6.1 Cross-Breaking Strength — The material shall be tested by the method described in Appendix G. The results shall be stated as mean cross-breaking strength in N/mm^2, together with the coefficient of variation, and shall meet the requirements, given in Table 1.

6.2 Compressive Strength — When required by the purchaser the materials shall be tested by the method described in Appendix H. The results shall be stated as ' mean compressive strength', in N/mm^2, together with the coefficient of variation, and shall meet the requirements given in Table 1.

7. THERMAL PROPERTIES

7.1 Coefficient of Linear Expansion — The material shall be tested by the method described in Appendix J. The results shall be stated as mean coefficient of linear expansion over the temperature range, $\times 10^6$ per °C, and shall meet the requirements given in Table 1.

7.2 Maximum Thermal Shock Temperature — When required by the purchaser the materials shall be tested by the method described in Appendix K. The results shall be stated as maximum thermal shock temperature in °C and the limits shall be agreed between the purchaser and the manufacturer.

8. GENERAL PROPERTIES

8.1 Porosity — The materials shall be tested in accordance with the method described in Appendix L or M as applicable, and shall meet the requirements given in Table 1.

The results shall be stated as:

a) Penetration in fuchsin dye test, or

b) Water absorption.

9. GUIDANCE FOR SELECTION OF CLASSES OF MATERIALS AND PROCESSES

9.1 The guidance for selection of classes of material and process for different application is given in Table 2.

TABLE 2 SELECTION OF CLASSES OF MATERIAL AND PROCESS

TYPE OF EQUIPMENT (1)	CLASS OF MATERIAL (2)	TYPE OF PROCESS (3)
High voltage insulators	Classes 3, 4, 5 and 6 (glazed)	Plastic methods
Low voltage insulators	Classes 1 to 6 (glazed or unglazed)	Die pressing

APPENDIX A

(*Clauses* 4.3, B-3, D-3, E-3 *and* F-3)

PREPARATION AND CONDITIONING OF TEST PIECES

A-1. CLEANING

A-1.1 Before conditioning, clean the test pieces free from surface dust and grease.

A-2. CONDITIONING

A-2.0 The test pieces shall be conditioned as follows.

A-2.1 Dry Conditioning — Unless otherwise specified, condition the test pieces for 18 to 24 hours in an atmosphere at 27 ± 5°C and 65 ± 5 percent relative humidity.

A-2.2 Wet Conditioning — Immerse the test piece in distilled water at a temperature of 23 ± 5°C for 18 to 24 hours. Remove the test piece, wipe its surface dry and commence the test after the test piece has been exposed to room conditions for 10 minutes.

A-2.3 Hot Conditioning — Heat the test piece in an oven or furnace in air to the specified temperature, the time of heating being sufficient to ensure that the whole test piece has reached that temperature. Carry out the test in the oven or furnace at the specified temperature.

A-2.4 Ground Conditioning — When it is desired to measure the characteristics of a ceramic material with a ground surface, grind the test piece on the relevant portions to a state of finish as nearly as possible similar to that which would be used in practice.

After grinding, clean the test piece by washing in water and a suitable solvent and then heat to a temperature of at least 500°C. Subject the test piece to the appropriate conditioning before testing.

NOTE — When the application of a ceramic material makes it necessary to determine the properties under conditions other than the standard condition, state this at the time of enquiry.

APPENDIX B

(*Table* 1, and *Clause* 5.1)

DETERMINATION OF DIELECTRIC DISSIPATION FACTOR AND PERMITTIVITY

B-1. Test Pieces — The test piece is a flat disc having dimensions giving a suitable capacitance for the apparatus used.

For the measurement of permittivity, grind the disc to bring the opposite faces flat and parallel.

B-2. Electrodes — The electrodes are of one of the following forms:

a) Fired-on silver films of adequate thickness, of the type commonly applied to ceramic materials;

b) Metal films of adequate thickness deposited in vacuo either by sputtering or volatilization;

NOTE — These films should be non-oxidizable and of high conductivity.

c) Mercury; and

d) Tinfoil, applied using the smallest possible amount of petroleum jelly or silicons grease as adhesive.

B-3. Conditioning of Test Pieces — Condition the test piece in accordance with Appendix A.

B-4. Test Conditions — Carry out the test at room temperature and in a dry atmosphere.

B-5. Frequency — Make the measurement at a frequeney of 1 MHz or at audio frequencies if so required.

B-6. Apparatus and Method of Measurement — For tests at audio and radio frequencies use the apparatus and method specified in IS : 4486-1967* or any other method which may be shown to give the same results.

B-7. Number of Test Pieces — Three test pieces shall be tested.

B-8. Results — State the mean of the three results for the requirements of **5.1** and also the temperature at the time of the test.

APPENDIX C

(*Table* 1, and *Clause* 5.2.1)

DETERMINATION OF TEMPERATURE COEFFICIENT OF CAPACITANCE OF THE MATERIAL

C-1. Test Pieces — The test pieces are of dimensions giving a suitable capacitance for the apparatus used.

C-2. Electrodes — The electrodes are of one of the following forms:

a) Thin continuous films of fired-on silver of adequate thickness, of the type commonly applied to ceramic materials, or

b) Metal films of adequate thickness deposited in vacuo either by sputtering or volatilization.

The electrodes completely cover the appropriate surfaces of the test piece.

---

*Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metres wavelengths.

C-3. Conditioning of Test Pieces — Condition the test piece in a temperature of 105 ± 20°C for at least 2 hours.

C-4. Frequency — Make the measurement at a frequency of approximately 1 MHz.

C-5. Test Condition — Make the measurement in conditions of low relative humidity at temperatures of 27 ± 5°C, 85 ± 5°C and then again at 27 ± 5°C or at a series of temperatures agreed between the manufacturer and the purchaser.

C-6. Method of Measurement — Use any method and apparatus having the requisite stability and sensitivity for measuring small capacitance change.

If the measurement is made by connecting the test piece in the tuning circuit of an oscillator, ensure that the driving circuit of the oscillator is such that the frequency of oscillation is independent of the power factor of the capacitors in the tuning circuit. No well-known oscillator meets this condition exactly, but the transitron meets it nearly enough for most purposes. Take precautions to prevent the deposition of moisture in the heating and cooling process and to keep the apparatus free from draught.

C-7. Number of Test Pieces — Three test pieces shall be tested.

C-8. Results — State the temperature coefficients of the three test pieces.

APPENDIX D

(*Table* 1, and *Clause* 5.3)

ELECTRIC WITHSTAND STRENGTH AT POWER FREQUENCY

D-1. Test Pieces* — The test piece is as shown in Fig. 1.

D-2. Electrodes — The electrodes are one of the following:

a) Thin continuous films of fired-on silver of adequate thickness on the areas indicated in Fig. 1, or

b) Metal films of adequate thickness deposited in vacuo either by sputtering or volatilization.

D-3. Condition of Test Pieces — Condition the test pieces in accordance with Appendix A.

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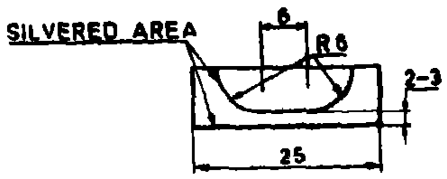
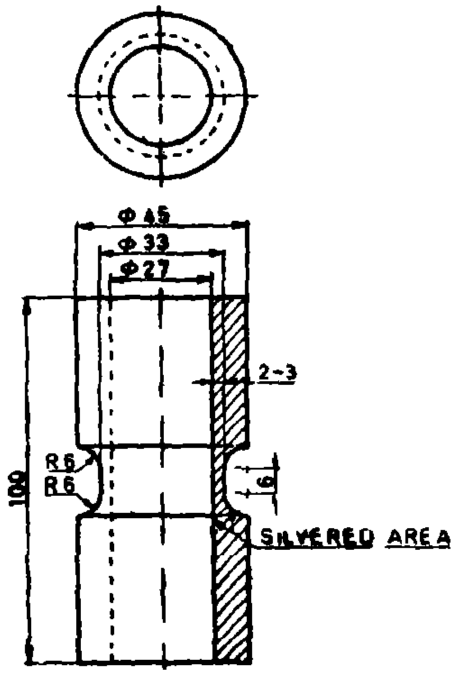
*The test piece or the immersion medium may not necessarily be suitable for a test to determine the breakdown strength of the material.



1A Small Size Test Piece



1B Bigger Size Test Piece

All dimensions in millimetres.

FIG. 1 FORM OF TEST PIECE AND ELECTRODES FOR DETERMINATION OF POWER FREQUENCY ELECTRIC STRENGTH

D-4. Immersion Medium* — Carry out the test with the test pieces immersed in transformer oil conforming to the requirements of IS : 335-1972†.

---

*The test piece or the immersion medium may not necessarily be suitable for a test to determine the breakdown strength of the material.

†Specification for new insulating oils for transformers and switchgear (*second revision*).

D-5. Method of Measurement — The test voltage is alternating and of a frequency in the range 48 Hz to 62 Hz. It is of approximately sine wave form and the ratio of the peak value to the rms value is within the limits of

$$\sqrt{2}\ (1 \pm 0{\cdot}05) \text{ that is } 1{\cdot}33 \text{ to } 1{\cdot}49$$

The test voltage is expressed as its peak value divided by $\sqrt{2}$ and is determined by means of a peak or other type of voltmeter connected across the output winding of the transformer. Alternatively it may be measured by means of a voltmeter connected across the input winding or across a portion of the output winding or across a special voltage winding. Whichever method is adopted, check the voltage measuring equipment, if necessary, against a sphere gap connected to the output of the testing transformer. For details of this method make reference to IS : 1876-1961*.

Apply the voltage between the electrodes and raise to the full test voltage given in Table 1 as rapidly as is consistent with its value being observed within the limits of accuracy and without any transient over-voltage. Maintain the test voltage for 1 minute.

D-6. Number of Test Pieces — Six test pieces shall be tested.

D-7. Results — All six test pieces shall withstand this test.

APPENDIX E

(*Table* 1, and *Clause* 5.4)

DETERMINATION OF SURFACE RESISTIVITY

E-1. Test Pieces — The test pieces are discs as shown in Fig. 2.

E-2. Electrodes — The electrodes are thin continuous films of fired-on silver covering the areas shown in Fig. 2. When it is desired to avoid heating the test piece, use graphite electrodes and state this in reporting the results.

E-3. Conditioning of Test Pieces — Condition the test pieces in accordance with Appendix A.

E-4. Test Conditions — Carry out the test at 27 ± 5°C and relative humidity of 65 ± 5 percent.

E-5. Apparatus and Method of Measurement — Measure the resistance between the 30 mm disc electrode and the ring electrode 1 minute after the application of a steady dc voltage of 500 volts, using the large ring electrode as a guard.

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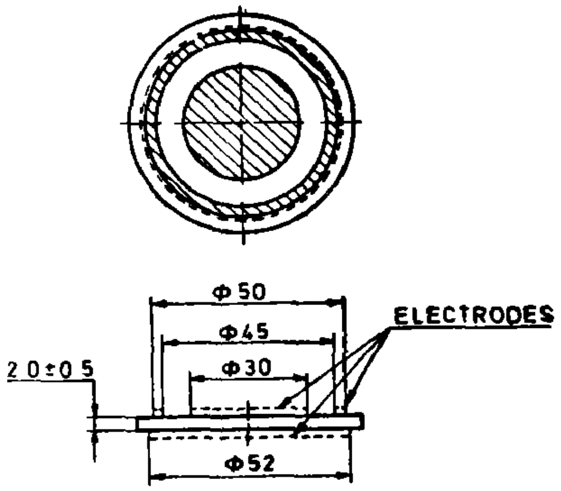
*Method for voltage measurement by means of sphere-gaps (one sphere earthed).



All dimensions in millimetres.

FIG. 2 TEST PIECE AND ELECTRODES FOR DETERMINATION OF SURFACE RESISTIVITY AND VOLUME RESISTIVITY

Use any apparatus which provides a guarded resistance measurement under the above conditions.

With the test pieces shown in Fig. 2 the surface resistivity, in megohms, is the measured resistance in megohms × 15·5.

E-6. Number of Test Pieces — Six test pieces shall be tested.

E-7. Results — State the geometric mean of the results in megohms.

E-8. Where required, this test may be carried out in accordance with IS : 3396-1965*.

APPENDIX F

(*Table* 1, and *Clause* 5.5)

DETERMINATION OF VOLUME RESISTIVITY

F-1. Test Pieces — The test pieces are discs of the material, as shown in Fig. 2.

F-2. Electrodes — The electrodes are thin continuous films of fired-on silver as indicated in Fig. 2. For temperatures above 600°C sprayed nickel electrodes are recommended.

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*Methods of test for volume and surface resistivities of electrical insulating materials.

F-3. Conditioning of Test Pieces — Condition the test pieces in accordance with Appendix A.

F-4. Apparatus and Method of Measurement — Measure the resistance between the two disc electrodes using a steady dc voltage of 500 volts for tests at a temperature of 27°C, or 50 volts at temperature of 300°C or 600°C. Connect the ring electrode as a guard.

For tests at 27°C or 300°C, make the measurement 1 minute after the application of the voltage. For tests at 600°C, make the measurement 1 minute after the application of the dc voltage, reverse the polarity of the voltage and make a second measurement 1 minute after the reversal; take the mean of these two measurements as the measured resistance.

Use any apparatus which provides a guarded resistance measurement under the above conditions.

With the test pieces shown in Fig. 2 the volume resistivity is given by:

$$\frac{\text{Measured resistance in megohms} \times 7\cdot1}{\text{Actual thickness of the test piece in cm}}$$

The units being megohm-centimetres.

F-5. Number of Test Pieces — Six test pieces shall be tested.

F-6. Results — State the mean of the six results. Take the geometric mean of the readings for the calculation of the resistivity of the pieces.

F-7. Where required, the test may be carried out in accordance with IS : 3396-1965*.

APPENDIX G

(*Table* 1, and *Clause* 6.1)

DETERMINATION OF CROSS-BREAKING STRENGTH

G-1. Test Pieces — When the materials are to be processed in the plastic condition, extrude a sample into a solid rod of circular cross-section of diameter 10 ± 2 mm, and a minimum length of 120 mm (fired dimensions).

When the materials are to be processed by pressing in steel dies, sample shall be pressed to give a fired test piece having a minimum length of 120 mm and the approximate square cross section of side 10 ± 2 mm.

G-2. Conditions of Test — Carry out the test under room conditions.

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*Methods of test for volume and surface resistivities of electrical insulating materials.

G-3. Method of Test — Support the test piece horizontally on two supports, of a circular cross section of 5 mm radius, the lines of support being 100 mm apart. Apply the load by means of a stirrup, or its equivalent, midway between the supports; round the contacting edge of the stirrup or other means to a radius of 5 mm. The lines of support and the edge of the stirrup, or equivalent, are at right angles to the length of the test piece.

Apply the load at the rate of not more than 3 percent of the expected breaking load per second, and proceed until rupture occurs. Record the load in N on rupture and the diameter (or sides) of the test piece.

Calculate the cross breaking strength according to whichever of the following formulae applies

Circular cross-section $\frac{80\,P}{\pi d^3}$

Near square cross-section $\frac{15P}{a_1 a_2^2}$

where

P = maximum load in N,

d = diameter of circular test pieces in mm,

a_1 = side of near square cross section at right angles to the direction of the applied load in mm, and

a_2 = side of near square cross section in the direction of the applied load in mm.

G-4. Number of Test Pieces — Six test pieces shall be tested.

G-5. Results — Calculate the mean of the six results and the coefficient of variation. Include in the statement of the results the nominal diameter of side of the square of test piece.

APPENDIX H

(*Table* 1, and *Clause* 6.2)

DETERMINATION OF COMPRESSIVE STRENGTH

H-1. Test Piece — The test piece is a solid cylinder, preferably 10 ± 2 mm in diameter and 10 ± 2 mm long.

Alternatively a test piece 20 ± 2 mm in diameter and 20 ± 2 mm long may be used.

The flat faces are ground plane and parallel.

H-2. Conditions of Test — Carry out the test under room conditions.

H-3. Method of Test — Perform the test in a normal compression-testing apparatus, preferably with self-aligning loading surfaces.

Place sufficient resilient material to avoid local stress concentration between the plane ends of the test pieces and the metal plates.

NOTE — Stiff cardboard approximately 3 mm thick has been found to be a suitable resilient material.

Apply the load at a rate not greater than 3 percent of the expected breaking load per second.

Calculate the compressive strength as $\frac{P}{A}$

where

P = the load in N at rupture, and

A = the area of cross-section of the specimen in mm^2.

The nominal diameter is stated.

H-4. Number of Test Pieces — Six test pieces shall be tested.

H-5. Results — State the mean maximum load in N/mm^2. State also the nominal diameter of the test pieces, and the thickness and type of resilient material used.

APPENDIX J

(*Table* 1, and *Clause* 7.1)

DETERMINATION OF COEFFICIENT OF LINEAR EXPANSION

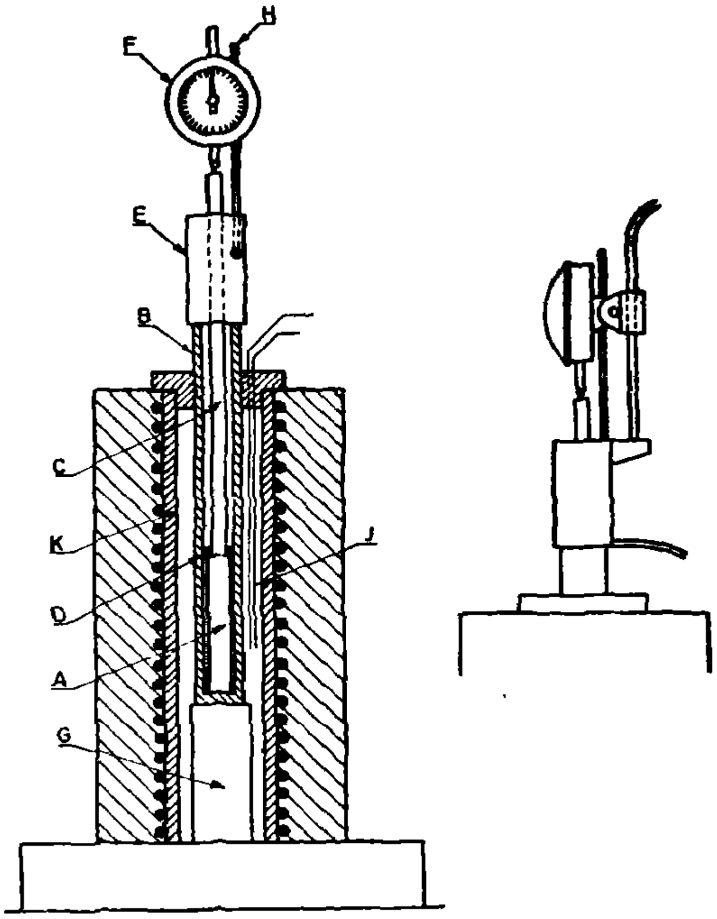
J-1. Test Piece — The test piece is in the form of a rod approximately 100 mm long and 10 to 20 mm diameter, or other suitable size.

Grind the two end surfaces so that they are plane and at right angles to the axis of the rod.

J-2. Method of Test — The form of apparatus is shown in Fig. 3, and is suitable for general use up to 1 000°C.

With a rate of temperature-rise of 5°C per minute, record the temperature and dial gauge readings at intervals of 2 minutes until the desired maximum temperature has been attained.

Correct the expansion figures by adding the expansion due to an equivalent length rod of fused silica to the expansion recorded. The coefficient of linear expansion for fused silica is 0.50×10^{-6} for the range 20°C to 100°C and 0.55×10^{-6} for the range 100°C to 500°C.



A = Test piece.
B = Fused silica tube.
C = Fused silica rod.
D = Refractory centralizing washer.
E = Water-cooled jacket and gauge support.
F = Calibrated dial gauge.
G = Refractory support.
H = Thermometer.
J = Thermocouple.
K = Refractory furnace tube.

FIG. 3 APPARATUS FOR DETERMINATION OF COEFFICIENT OF EXPANSION

Other methods of measurement may be used, for example, micrometer, microscope or interferometer having least count equal to 0·001 mm.

J-3. Results — Make not less than three determinations, plot a curve and calculate the mean coefficient of linear expansion.

APPENDIX K

(*Clause* 7.2)

DETERMINATION OF MAXIMUM THERMAL SHOCK TEMPERATURE

K-1. Test Piece — The test piece is in the form of a solid cylinder 20 ± 1 mm diameter and 20 ± 1 mm long, and is prepared by the same process as for production articles.

K-2. Method of Test — Heat six test pieces to the first test temperature, and maintain at that temperature for at least 30 minutes. Arrange the furnace so that the test pieces can fall freely into a bath of cold running water at 10-20°C. Quench the test pieces in this manner for at least 5 minutes and then examine for cracks with the aid of a dye; if there are no visible signs of failure replace the test pieces in the furnace and repeat the cycle at a temperature 10°C higher. Repeat this process and state the lowest temperature at which two or more failures occur as the maximum thermal shock temperature. Commence the test at a temperature which all test pieces will satisfactorily withstand. When the maximum thermal shock temperature exceeds 200°C make the temperature increments 25°C.

APPENDIX L

(*Table* 1, and *Clause* 8.1)

TEST FOR POROSITY BY FUCHSIN DYE PENETRATION

L-1. Porcelain fragments from the insulators or, by agreement, from representative pieces of porcelain fired adjacent to them shall be immersed in a 1 percent alcohol solution of fuchsin (1 g fuchsin in 100 g denatured spirit) under a pressure of not less than 15×10^6 N/m^2 for a time such that the products of the test duration in hours and the test pressure in N/m^2 is not less than 180×10^6.

L-2. The fragments shall then be removed from the solution, washed, dried and again broken.

L-3. Examination with the naked eye of the freshly broken surfaces shall not reveal any dye penetration. Penetration into small cracks formed during the initial breaking shall be neglected.

APPENDIX M

(*Table* 1, and *Clause* 8.1)

TEST FOR POROSITY BY WATER ABSORPTION

M-1. Test Pieces — The test pieces are at least six in number and their total mass is between 80 g and 100 g. They are clean at the start of the test.

M-2. Conditioning of Test Pieces — Heat the test pieces to 110°C in a dry atmosphere for at least 2 hours and cool in a desiccator.

M-3. Method of Test — Weigh the conditioned test pieces and then immerse completely in distilled water, which is brought to the boiling point and kept boiling for not less than 30 minutes.

Allow the test pieces, still immersed completely in the water, to cool to normal temperature over a period of not less than 6 hours. Take the test pieces from the water and wipe the surfaces with a cloth which has been soaked in water and well wrung; support them in still air at normal temperature. After 5 minutes, and before 10 minutes from the time of removal from the water, re-weigh the test pieces. Take the weighing to the nearest milligram.

M-4. Results — Calculate the percentage of water absorption as:

$$\frac{\text{Weight of moisture absorbed} \times 100}{\text{Initial weight of conditioned test pieces}} \text{ percent}$$